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GROUNDWATER GEOLOGY IN WESTERN ILLINOIS, NORTH PART

A Preliminary Geologic Report

Robert E. Bergstrom

Service activities concerning groundwater are performed jointly by the Illinois State Geological Survey and the Illinois State Water Survey

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ABSTRACT

Geologic conditions controlling the availability of groundwater in the northern part of western Illinois are generally favorable for domestic supplies, but range from unfavorable to very favorable for large municipal and industrial supplies. This report presents a summary of groundwater principles, evaluates the geology in terms of the availability of groundwater for various purposes, and discusses methods of developing groundwater supplies. The maps and figures show: 1) areal and vertical distribution, type, and water-yielding character of upper bedrock formations, and 2) probability of occurrence of sand and gravel aquifers. Summary logs of 26 key wells at selected locations give representative sequences of subsurface strata.

INTRODUCTION

Water is a natural resource that is more basic to the economy of Illinois than her mineral deposits or her well known rich prairie soils. Billions of gallons of water are required daily by farms for crops and livestock; by industries for cooling, processing, and power generation; and by cities for household use and public services.

Farm crops, the greatest single user of water, extract from the soil the water stored from rainfall and irrigation. Cities and industries use surface water from streams or lakes or groundwater from wells. They may get water supplies nearby or from a considerable distance.

The extent to which groundwater may be obtained in a region is of great economic importance because (1) the total area in which surface water is present right where it is needed is small and (2) surface supplies usually involve considerable capital outlay for collection and treatment. Therefore farms, suburban communities, and small municipalities and industries depend heavily upon groundwater as a source of supply.

The availability, quantity, and quality of groundwater depend upon the nature and arrangement of the earth materials beneath the surface, that is, upon geologic conditions. Any groundwater supply, whether for small domestic needs or for the large requirements of a city or industry, can be obtained only where there are rocks that can transmit water. Rocks which transmit water are said to be permeable and are technically called aquifers. Because geologic conditions change from place to place, in some areas groundwater is readily available for all purposes whereas in others it is difficult to obtain even small supplies.

Knowledge of the distribution and character of aquifers in any area is necessary to develop groundwater supplies properly. This report provides infor-

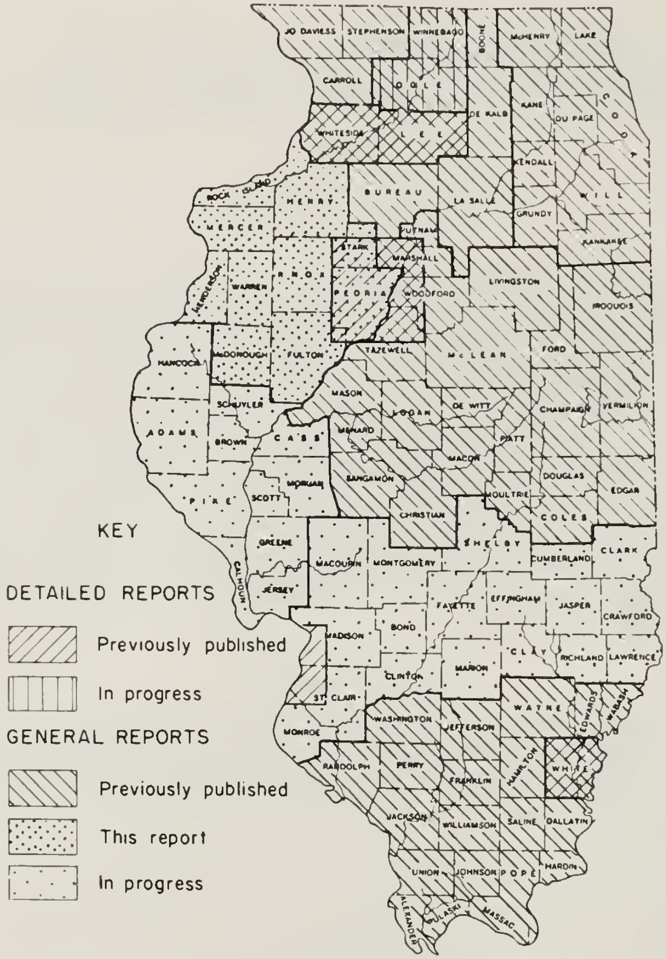

Fig. 1. - Index map of reports on groundwater geology in Illinois published since 1950 or in progress.

mation on the availability of groundwater in the northern part of western Illinois and discusses principles of groundwater occurrence and development. It is part of a program aimed toward improving water supplies on Illinois farms, in which the Illinois State Geological Survey is cooperating with the Extension Service of the Agricultural Engineering Department, College of Agriculture, University of Illinois.

The report is the fifth in a series.* It describes the northern part of Agricultural Extension District 2 and includes the following ten counties: Fulton, Henderson, Henry, Knox, McDonough, Mercer, Peoria, Rock Island, Stark, and Warren (figs. 1 and 2).

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* Previous reports in the series, listed in "Suggested Reading" on page 21 and shown by area in figure 1, are available upon request from the Survey in Urbana.

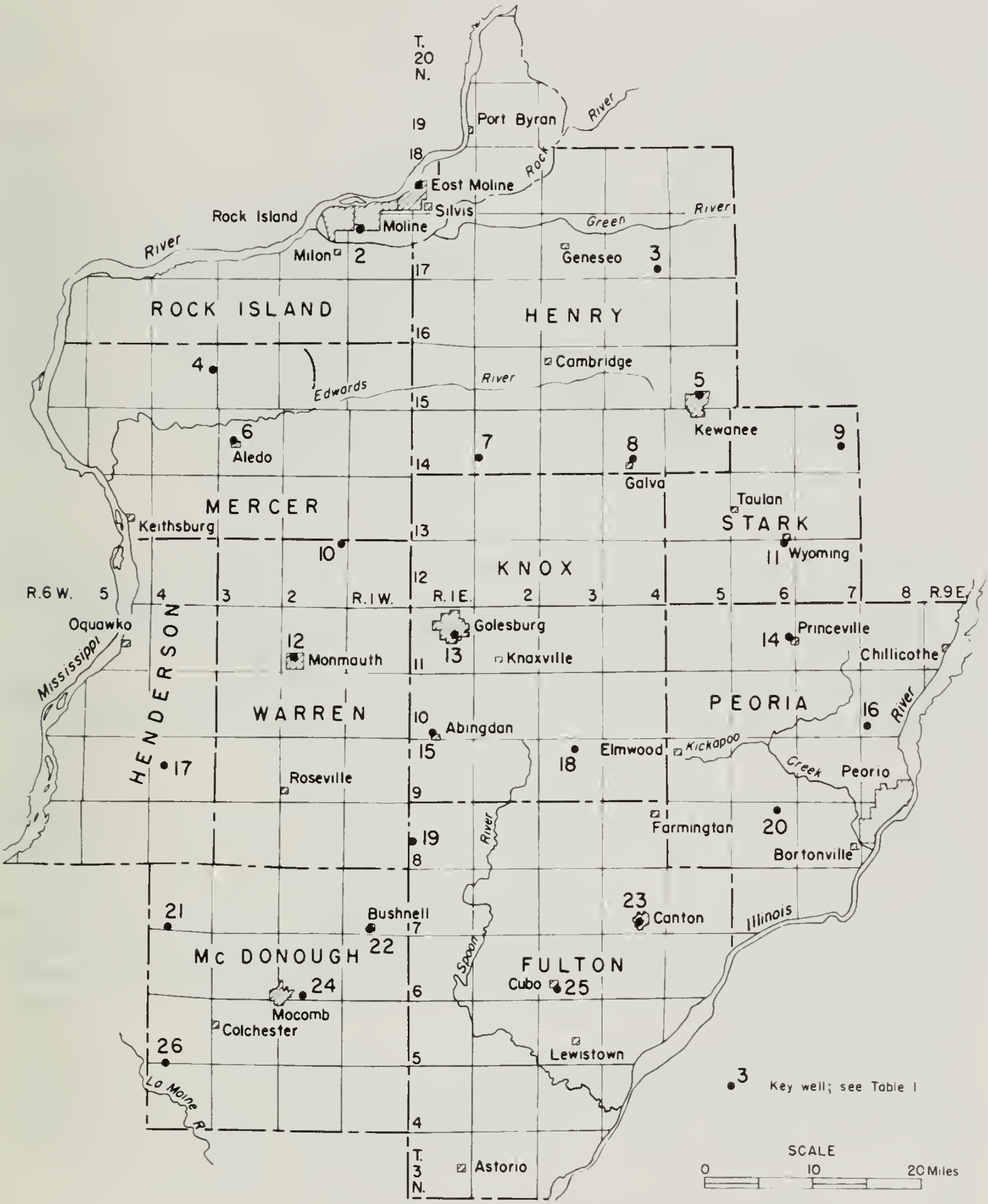

Fig. 2. - Western Illinois, north part, showing location of key wells.

The region has an area of about 5,800 square miles and a population of slightly more than half a million. Much of it is highly productive agricultural land on which livestock and grain farming are the principal enterprises. Peoria and the Tri-Cities (Rock Island, Moline, and East Moline) are the two main industrial centers of the region.

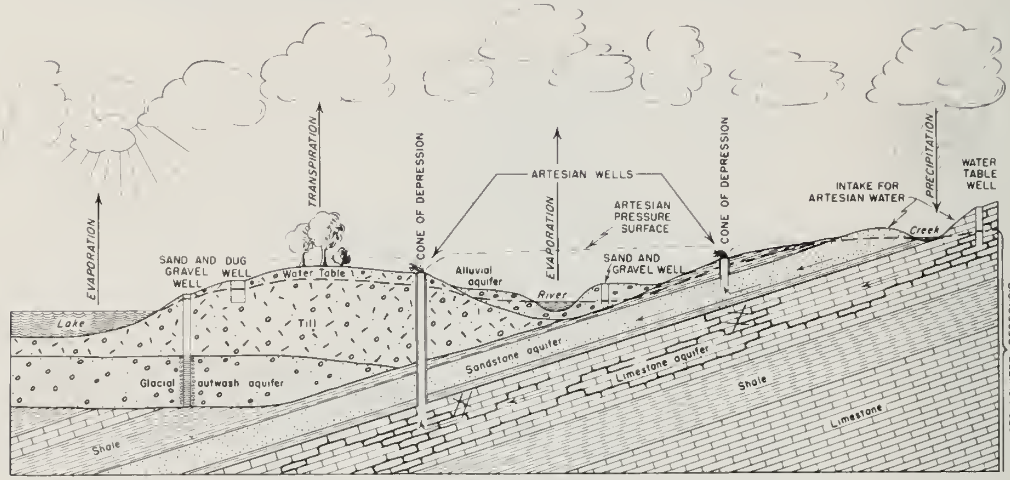

Fig. 3. - Source, movement, and occurrence of groundwater.

Drilling contractors in western Illinois have assisted in the preparation of this report by providing large numbers of logs of water wells for the files of the Geological Survey and by supplying information on specific problems of occurrence of water-yielding materials and drilling conditions.

I am also pleased to acknowledge the assistance given by members of the Groundwater Division and other Divisions of the State Geological Survey.

OCCURRENCE OF GROUNDWATER

Because groundwater occurs beneath the surface of the earth and is hidden from view it is often regarded as somewhat mysterious. Throughout human history many fanciful explanations have been presented to describe its source, movement, and occurrence. Scientific study has shown, however, that groundwater obeys certain physical laws or principles which are relatively simple and easily understood, although complex in detail. Our present understanding of the source, movement, and occurrence of groundwater is shown diagrammatically in figure 3.

Groundwater is supplied by rain, snow, or ice that falls on the earth from the atmosphere and seeps into the ground. The tremendous quantity of water that falls on the land surface by precipitation is seldom realized, but it is far more than adequate to supply our vast groundwater reservoir. Most of it falls into the oceans, runs off in streams, or is returned to the atmosphere by evaporation and transpiration.

The remainder filters slowly down into the ground until it reaches a level below which all available openings are filled with water. The top of this saturated zone is called the water table. When a well is drilled or dug, it is dry until it penetrates the zone of saturation; the position of the water table is then shown by the level at which water stands in the well. The water table is not a level surface but conforms more or less to the principal features of the land surface. Where the water table intersects the land surface, groundwater is

discharged in the form of springs that feed perennial streams, lakes, and swamps. The water table does not remain stationary but fluctuates in response to the loss or gain of groundwater.

Groundwater moves under the influence of gravity or in response to other natural pressure differentials toward points of lowest pressure, which are always places of discharge, such as springs, marshes, or pumped wells. This movement is slow because there is friction between the water and the pore or crack surfaces.

Groundwater is said to be under water-table conditions where the top of the zone of saturation is free or not confined under pressure other than surface atmospheric pressure. Under these conditions and under the influence of gravity groundwater moves freely, hindered only by friction, in the direction of the slope of the water table.

Groundwater is said to be confined, or under artesian conditions, where the saturated permeable aquifer is overlain by a less permeable material that restricts the upward movement of the groundwater. Under these conditions, the water in the confined strata is subject to pressure that causes the water in a well to rise above the top of the aquifer. Where sufficient pressures are encountered in an artesian well, the water may rise above the land surface and make a flowing well.

To supply a pumped or flowing well, groundwater must move through the earth materials toward the well. Under water-table conditions, pumping lowers the water table in the vicinity of the well and induces the flow of groundwater toward the well from adjacent areas. Under artesian conditions, pumping causes a reduction of hydrostatic pressure in the vicinity of the well, which induces the flow of groundwater toward the well. The depression in the water table or in the artesian pressure surface, which results from pumping, is in the form of an inverted cone with the well at the center. It is called the cone of depression (fig. 3).

Groundwater is not everywhere available in sufficient quantities to satisfy requirements. The availability of groundwater in humid regions such as western Illinois is basically dependent upon the presence of aquifers. Some earth materials, such as sand and gravel, have characteristics that make them particularly good aquifers. Other earth materials, such as clay and shale, may contain even more water per cubic foot than sand and gravel, yet resist the movement of groundwater through them to such a degree that they will not yield appreciable quantities of water to a well. The value of an aquifer depends upon the type, size, number and degree of interconnection of the openings that may store and conduct groundwater.

In western Illinois, the important aquifers are sand and gravel, sandstone, limestone, and dolomite (a limestone-like rock rich in magnesium). Sand and gravel deposits are water-yielding because the openings between the individual grains are large enough to allow relatively rapid movement of water. Good water-yielding sand and gravel deposits are composed of grains that are nearly all the same size and coarser than granulated sugar. If large amounts of clay and silt are present in the sand and gravel deposits, the openings between the larger grains are clogged and the movement of water is retarded. Sand and gravel deposits in western Illinois range in thickness from a few inches to hun-

SYSTEM	FORMATION THICKNESS (Ft)	GRAPHIC LOG	ROCK TYPE DRILLERS' TERMS ( )	WATER-YIELDING CHARACTERISTICS; DRILLING AND WELL CONSTRUCTION DETAILS
PLEISTOCENE	0-250' Sankoty sand in Peoria region		Unconsolidated glacial deposits, loess (windblown silt) and alluvium (Drift, surface, overburden)	Water-yielding character variable. Large yields from thicker sand and gravel deposits in bedrock valleys. Wells usually require screens and careful development
PENNSYLVANIAN	0-475'		Mainly shale with thin sandstone, limestone, and coal beds (Coal measures)	Generally unfavorable as aquifer. Locally, domestic and farm supplies obtained from thin limestone and sandstone beds. Casing usually required
MISSISSIPPIAN	St. Louis - Salem 0-75'		Limestone	Water-yielding where creviced. Too thin to be important source of water in area
	Warsaw 0-100'		Shale	Not water-yielding at most places. Casing required
	Keokuk - Burlington 0-225'		Cherty limestone (First lime)	Generally creviced and water-yielding. Wells penetrate limestone from 30 to more than 150 feet. Dependable aquifer for farm supplies in much of area.
	Kinderhook 0-275'		Shale with limestone and dolomite	Not water-yielding at most places. Locally limestones within shale are source of small farm supplies. Casing required
DEVONIAN	25-200'		Limestone with sandstone in lower part (Second lime)	Devonian limestone locally water-yielding from crevices. Silurian dolomite more dependable aquifer for farm supplies in most areas. Satisfactory wells may require penetration from 25 to 150 feet into Silurian. Dolomite usually "tighter" in lower half. Oil sand ("Hoing") occurs in lower part of Devonian in southwest Mc Donough County.
SILURIAN	0-350'		Dolomite. Argillaceous near base. Lower part cherty (Niagaran)	
ORDOVICIAN	Maquoketa 25-250'		Green to blue shale with limestone and dolomite beds	Not water-yielding at most places. Casing required
	Galena - Platteville 300-325'		Dolomite with shaly zone near middle. Some limestone in lower part (Trenton)	Not important as aquifer. Creviced dolomite probably yields some water to wells drilled into underlying sandstones.
	Glenwood - St. Peter 125-350'		Sandstone, clean, white. Dolomite, shale at top. Clay and chert at base (St. Peter)	Dependable source of groundwater. Water more highly mineralized to east and south where formation is deeper. Well liner usually set opposite caving zone in lower part.
	Shakopee 175-275'		Dolomite with some shale and sandstone	Not important as aquifer. Liners in lower St. Peter sandstone commonly seated in upper part of Shakopee
	New Richmond 50-150'		Sandstone with some dolomite	May yield some water to wells penetrating Ironton-Galesville sandstone.
	Oneota 120-365'		Dolomite with some sandstone beds (Lower Magnesian)	Not important as aquifer
CAMBRIAN	Trempealeau 180-270'		Dolomite with some sandstone at top	Crevices may yield water to wells penetrating Ironton-Galesville sandstone.
	Franconia 100-200'		Green sandstone, shale, and dolomite.	Not important as aquifer
	Ironton-Galesville 125-215'		Sandstone, clean, white. Thin dolomite beds at top. (Dresbach)	Widespread important aquifer for industrial and municipal supplies. Lower part of formation most permeable. Mineral content of water increases to east and south where formation is deeper
	Eau Claire 350-500'		Mainly shale and dolomite at top, grading to sandstone below	Not important as aquifer. Casing not required.
	Mt. Simon 1200'+		Sandstone with red shale beds	Water-yielding. Upper part sometimes penetrated by larger municipal and industrial wells. Great depth of formation and high mineralization of water restrict its use.
PRE-CAMBRIAN			Granite and other crystalline rocks extending to great depth.	

Fig. 4. - Generalized column of rock formations in western Illinois, north part.

dreds of feet. Deposits a few feet or more thick are often suitable aquifers for drilled wells. Thinner deposits of sand and gravel in otherwise tight earth materials are suitable aquifers only for dug or augered wells of large diameter.

Water-yielding sandstone formations transmit groundwater through the openings between sand grains. As in sand and gravel deposits, any material that clogs the openings between the sand grains reduces the water-transmitting capacity of the formation. Sandstone formations contain variable amounts of cement, and some sandstones are so thoroughly cemented that water moves primarily through joints and fractures.

The major sandstone aquifers in western Illinois, the Glenwood-St. Peter and Ironton-Galesville sandstones (fig. 4), are thick, well sorted, and loosely cemented, and they are widely used as sources of municipal and industrial supplies. Fine-grained, poorly sorted, well cemented sandstones occur at shallow depths in the Pennsylvanian formations in most of the area (figs. 4 and 5).

Tight, compact rocks like limestone and dolomite yield groundwater to wells from interconnected cracks and solution channels. Because these water-filled openings are irregular in size and distribution, the yields of closely spaced limestone or dolomite wells may be quite different. The Keokuk-Burlington limestone and the Silurian dolomite are well creviced at most places where they occur in the region and are usually a dependable source of groundwater for farm supplies (figs. 4 and 5).

GEOLOGY

The landscape of western Illinois has been shaped principally by running water and glacial ice. Glacial ice, advancing outward from centers of snow accumulation in Canada during the last Ice Age, transported a vast quantity of rock debris and in melting deposited it as a blanket that smoothed pre-existing irregularities and produced the broad flat upland plains of Mercer, Warren, McDonough, Henry, Stark, and Knox counties. Running water, which is ever modifying the surface by cutting into the land, carrying away soil and rock particles, and depositing them in river bottoms, has worked headward from tributaries of the Mississippi and Illinois rivers in Rock Island, Fulton, and Peoria counties to change some of the plains left by the glaciers to a rolling landscape of narrow divides and steep to gently sloping valley sides.

Low broad ridges rise above the flat upland plains in part of the region, such as northeastern McDonough, northwestern Fulton, and southeastern Knox counties. They are called moraines and are accumulations of mixed clay, silt, sand, pebbles, and boulders which were heaped up along the front of glaciers. The prominent moraine which crosses eastern Peoria, Stark, and Henry counties marks the western front of the latest glacier (Wisconsin) that advanced into the area (fig. 6). West of this moraine the glacial deposits are from earlier (Kansan and Illinoian) ice advances.

Advances of glacial ice greatly modified the drainage of northwestern Illinois. The ancient course of the Mississippi River in northern Rock Island County was eastward to the valley of what is now the Illinois River rather than southward past Port Byron. When this eastward course was blocked by a lobe of ice that advanced westward across the northern tip of Rock Island County (note Wisconsin glacial boundary in fig. 6) the Mississippi assumed its present southward course.

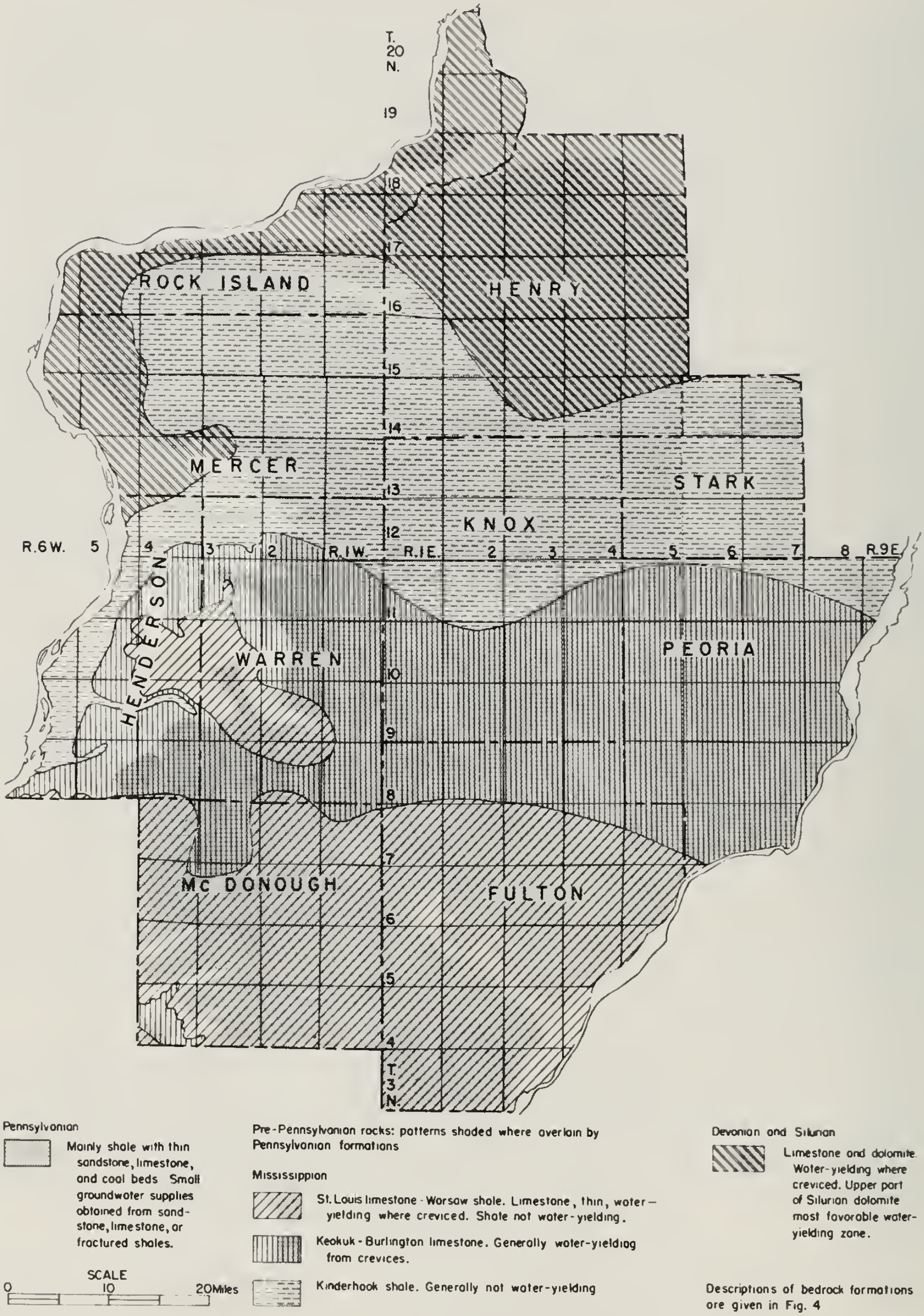

Fig. 5. - Areal distribution, type, and water-yielding character of upper bedrock formations (modified from Illinois Geologic Map, 1945).

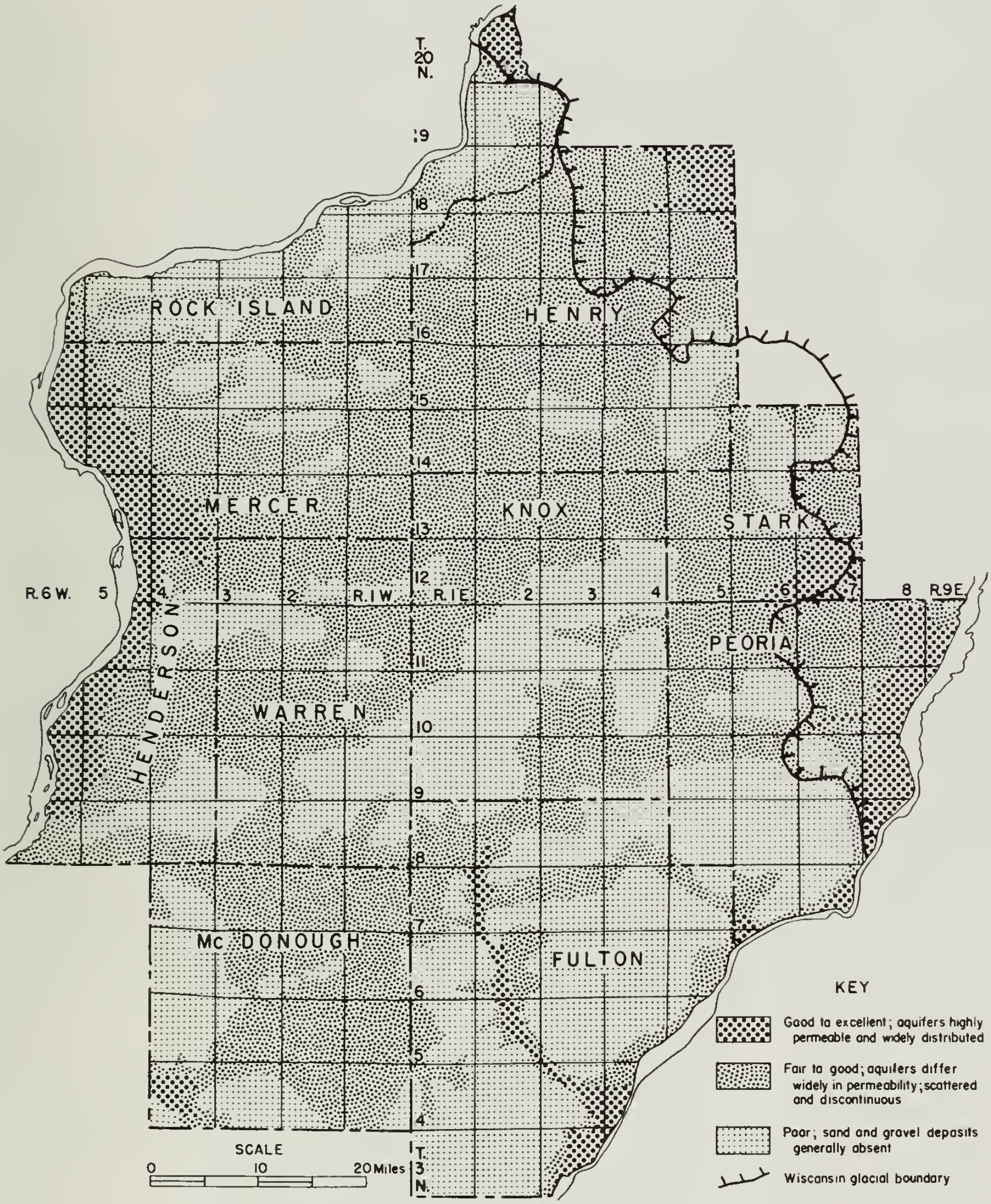

Fig. 6. - Probability of occurrence of sand and gravel aquifers.

The glacial deposits in western Illinois are complex. Areas overridden by glaciers are blanketed by unsorted rock debris, called till, deposited as the ice melted. Beyond the ice front, sediment-laden meltwaters escaped down valleys, partially filling them with deposits of sorted sand, gravel, and finer material. These deposits are called outwash. River flats, kept free of vegeta-

tion by frequent glacial flooding, were subject to wind erosion, and great volumes of silt were blown onto the uplands bordering the valleys to form loess. Loess, till, outwash, and the sediments of modern streams cover the bedrock surface in most of western Illinois.

Where glacial deposits form the surface mantle, much of our information about the bedrock and the topography that was developed on the bedrock before the glaciers advanced comes from records and samples of wells and borings. Study of well information and of rocks in areas where they crop out at the surface indicate that the upper surface of the bedrock is irregular, caused by ancient erosion, and that the rock consists of layers of shale, coal, limestone, dolomite, and sandstone arranged one upon the other like the pages of a book (fig. 4). Although they are firm compact rocks now, they were originally deposited as loose sediments in shallow seas that invaded the continent. The sediments were buried and hardened into solid rock during the several hundred million years after the seas retreated from Illinois. The rocks were later warped and tilted so that today they are no longer horizontal but dip southeastward 10 to 15 feet per mile.

The Pennsylvanian system of coal-bearing rocks (fig. 4) overlies older rocks with an angular relationship that indicates the older rocks were tilted to the south and eroded before the Pennsylvanian sediments were deposited over them. Thus successively younger rocks are encountered beneath the Pennsylvanian from north to south (fig. 5).

Although the regional dip of the bedrock is southeastward there are local upfolds (anticlines) and downfolds (synclines) that modify or reverse the regional dip. Drilling for oil has been concentrated mainly on anticline or dome structures in accordance with established exploration practice in many oil-producing areas. Oil has been produced for many years from the Colmar-Plymouth field, a low structural dome in southwestern McDonough County. Production is from the 12 to 15-foot thick Devonian "Hoing" sandstone (fig. 4).

Beneath the layered rocks are ancient crystalline rocks which form the "basement." The crystalline rock is chiefly granite, as is indicated by a few very deep borings in Illinois. Two oil tests in Lee County (fig. 1) encountered granite at depths of 3465 feet and 3760 feet.

DISTRIBUTION OF AQUIFERS

Sand and gravel beds occur in the unconsolidated material that glaciers and running water have deposited on the bedrock surface (fig. 3). Dolomite, limestone, and sandstone aquifers occur in the bedrock. The vertical sequence of earth materials in western Illinois is given in figure 4.

Figure 5 shows the areal distribution and water-yielding properties of the upper bedrock formations that are penetrated at land surface or beneath the glacial material.

In many places, particularly along the courses of streams or of glacial or preglacial drainage ways, sand and gravel deposits merit careful consideration as a source of groundwater. Figure 6 shows the probability of occurrence of sand and gravel aquifers. The area labeled "good to excellent" is underlain by thick glacial deposits, especially in major bedrock valleys, containing sand and gravel. Groundwater for domestic and farm supplies may be obtained in this area from small-diameter drilled wells in sand and gravel. Possibilities

for municipal or industrial wells are good to excellent, although test drilling is necessary to locate the best formation and site for the construction of high-capacity wells.

The area labeled "fair to good" in figure 6 has moderately thick glacial deposits that border the deep channels of bedrock valleys or fill minor valleys and include some sand and gravel. Groundwater for domestic and farm supplies may be obtained locally in this area from drilled wells in sand and gravel, but at some locations these deposits are absent and wells are drilled into the bedrock. The probabilities for obtaining supplies of water for industrial and municipal purposes are poor to fair. Extensive test drilling is likely to be necessary to locate water-yielding sand and gravel deposits suitable for such purposes.

The area labeled "poor" is primarily bedrock upland with glacial deposits thin or absent. Sand or gravel capable of supplying groundwater is rare, and most wells obtain water from the bedrock.

Several hundred feet below the formations shown in figure 5 are the deep sandstone aquifers, the Glenwood-St. Peter and Ironton-Galesville, sources of water for many municipalities and industries in northern Illinois (fig. 4). The Glenwood-St. Peter is less uniform in thickness and high permeability than the Ironton-Galesville but is about 1000 feet nearer the surface and in some places yields less highly mineralized water. The quality of the water in both aquifers becomes poorer toward the south and east as the aquifers deepen. Table 1 (p. 22-24) gives depths of formations, including the deep sandstones, as found in key wells in the area of study.

DEVELOPMENT OF GROUNDWATER SUPPLIES

Geologic Conditions That Affect Groundwater Development

The amount and quality of groundwater available in an area are controlled by geologic factors that must be considered in developing groundwater supplies. These factors, which are discussed relative to individual occurrences in other sections of this report, are summarized as follows:

1) Distribution of aquifers, including presence or absence, depth and thickness, and areal extent.
2) Nature of aquifers, including type of material, kind of openings (pores or crevices), and presence of substances which affect water quality.
3) Geologic structure, including regional and local dip of beds, faults, and jointing.
4) Distribution and nature of non-water-yielding materials.

The mere presence of an aquifer is not in itself enough to assure that a satisfactory groundwater supply can be obtained in a given area. Care must be taken to select the aquifer most suitable for the water supply required, to adapt the type and manner of construction of the well to the geologic conditions, and to place the well where it will best maintain the required standards of quality and quantity of water.

Unconsolidated Deposits

Where extensive water-yielding sand and gravel deposits are present in an area, consideration should usually be given to developing wells in them rather

than in the underlying bedrock. Sand and gravel wells may have one or more of the following advantages over bedrock wells, particularly over deep bedrock wells: shallower water levels, colder water, greater water yields to specific wells, and water of better mineral quality. The disadvantage of sand and gravel wells is the special construction needed to take full advantage of the water-yielding capacity of the aquifer.

High-capacity sand and gravel wells require the use of screens, which allows the flow of sand-free water into the bore. It is important in the development of sand and gravel wells that the size of the screen openings or slots be chosen on the basis of the size of the material to be screened. Therefore it is necessary that samples of the aquifer be obtained and analyzed for particle size to determine the correct size of the screen opening.

Development necessarily follows construction of a sand and gravel well. In proper development, the finer grained materials in the immediate vicinity of the well bore are drawn through the screen and removed, which leaves a natural graded filter that prevents pumping of sand and silt. Better results and yields may be obtained from some sand and gravel deposits by placing an "envelope" or "pack" of selected gravel or coarse sand between the deposit and the screen. The grain size of the particles in the gravel pack must have the proper relationship to the grain size and sorting of the formation and to the screen slot size to achieve the best results. The use of open pipe, or slotted pipe, or pipe filled with gravel should be avoided except in very coarse deposits where the well will yield far more water than is pumped.

The physical characteristics of sand and gravel deposits are generally more variable than those of bedrock formations. For this reason, groundwater development from sand and gravel sources usually requires test drilling prior to well design and construction. In areas where the presence of suitable aquifers is uncertain, a test-drilling program is necessary to determine whether suitable deposits are present and, if present, the best location for the well.

Test drilling is generally done by drilling small-diameter holes with cable tool (percussion) or with rotary drilling equipment. The test driller's report is an important part of the groundwater development program and should include the following information when obtainable: 1) driller's log of formations penetrated, 2) static water level and changes in water levels during drilling, 3) drilling time of the individual formations, 4) weight and viscosity of drilling mud, and 5) loss of mud or fluid during drilling. Samples of drill cuttings should be saved at a five-foot interval and also where there are changes in the type of material.

Conditions favorable for drilled wells in sand and gravel in western Illinois are found mainly in and along the Illinois, Mississippi, Spoon, and La Moine river valleys (fig. 6). In the Peoria region the Sankoty sand and younger glacial outwash deposits are among the most prolific aquifers in the State (fig. 4).

Driving a sand point is the quickest and most economical method of well construction but is practical only where small supplies of groundwater are needed and where such supplies are available from sand and gravel at shallow depths. Conditions are suitable for driven wells in the Illinois, Mississippi, Spoon, and La Moine valley bottoms and in certain parts of the Rock, Green, and Edwards river bottoms.

Large-diameter (2 to 5 feet) dug wells are most suitable in areas where the unconsolidated materials are fine-grained and cannot yield water readily to a drilled or driven well; therefore they are used widely throughout much of the area in which glacial material is thin and tight and is underlain by impermeable Pennsylvanian rocks. Large-diameter wells are excavated by hand, power auger, shovel, or bucket and can be excavated to depths up to about 100 feet. In areas where conditions are favorable for drilled or driven wells, the use of large-diameter dug wells is not recommended because of pollution and maintenance problems. The chief advantage of a large-diameter well is that it can store relatively large quantities of water. Short intermittent pumping of a large-diameter well does not require immediate release of water from the surrounding materials, and the well can refill slowly between times of pumping. Special sanitary precautions should be taken with large-diameter wells. (See Circular 14A, Illinois State Department of Public Health, Springfield.)

Bedrock Formations

Wells constructed in bedrock aquifers are generally less difficult to design because the well bore is usually left uncased and because the aquifers are more consistent over wider areas. Test drilling in bedrock aquifers is seldom done, particularly where records of prior drilling in the area are available.

In western Illinois the most important geologic factors affecting well construction in bedrock aquifers are: 1) type, thickness, depth, and permeability of aquifers, 2) ability of formations to sustain open hole without casing or lining, and 3) tendency of formations to yield silt or sand during pumping.

Creviced dolomite and limestone do not normally require casing or lining. However, where groundwater supplies are obtained from near-surface dolomite or limestone formations, with less than about 35 feet of overburden, there is danger of bacterial pollution. The open crevices provide little filtering or other purifying action, and polluted water may travel long distances through these openings.

Normal drilling procedure in the development of bedrock aquifers is to install surface casing to firm bedrock and to continue into the bedrock with an open hole. Where a bedrock formation is too weak to sustain an open hole, it may be necessary to continue the surface casing through the weak formation into a more competent underlying formation or to set liners. The most important caving zones requiring casing are in the Pennsylvanian, Warsaw, Kinderhook, and Maquoketa shales, and, at some localities, shale beds in the lower part of the St. Peter formation (fig. 4).

Caving of loose zones in sandstone formations, principally in the lower portion of the St. Peter and the Galesville, presents drilling difficulties. Wells to the lower portion of the St. Peter sandstone commonly use a "rat hole" drilled into the underlying formations to serve as a collector of loose sand.

Pumping of some mud, silt, or sand from high-capacity wells cannot always be avoided. Remedial measures must be taken when the pumping of fine materials becomes excessive. The State Geological Survey frequently assists in the solution of this problem by identifying the source and approximate depth of the materials, so that by installing casing or liners at the proper positions the discharge of materials may be reduced or eliminated. The most common materials

pumped with water are: 1) silt and clay, from overlying glacial deposits, that gain entry through leaks in surface casing or improperly seated surface casing, 2) silt and clay from weak shale or underclay zones that have been left uncased or are improperly cased, 3) clay and silt from open crevices and caves in the limestone, which are quite common in some areas, and 4) silt and fine sand from fractured sandstones.

Most of these problems can be corrected by installing casing or liners. In sandstone formations, however, casing may drastically affect the well yield. There are three common causes of excessive silt and sand pumpage from sandstone formations:

1) Drilling too small a hole in loose sandstone formations. The smaller the diameter of the well bore, the greater the velocity of water moving through the formation immediately around it; enlarging the diameter of the well bore or reducing the pumping rate decreases the velocity of water movement.

2) Setting the pump bowls opposite unprotected loose zones in the sandstone. Turbulence in the vicinity of the pump bowls causes enlargement of the hole.

3) "Shooting" loose sandstone zones with too much explosive and with too little regard for the condition of the sandstone.

Conditions are generally favorable in western Illinois for drilled wells in bedrock. The main aquifers exploited for farm supplies are the Keokuk-Burlington limestone and the Silurian dolomite (figs. 4 and 5, and table 1).

Large Groundwater Supplies

Development of groundwater supplies for municipal, industrial, and irrigation purposes requires technical advice and careful planning based on all available geologic and hydrologic data. The type, extent, thickness, depth, distribution, and water-yielding characteristics of aquifers in the area should be determined so that the available quantity of water may be estimated and plans made for proper well construction. Hydrologic data, such as yields of existing wells, pressure potential of various formations, and water quality, should also be determined as accurately as possible.

Information on geologic conditions pertaining to groundwater supplies at prospective well locations is available upon request from the State Geological Survey. The Survey maintains a current file of subsurface information including drillers' logs and samples of drill cuttings, from which specific data on formation characteristics are available for many areas in Illinois. It also publishes basic geologic studies of a regional nature. Information on well yields, water levels, and water quality is furnished by the State Water Survey.

Domestic Groundwater Supplies

Development of groundwater supplies for domestic and stock use differs from municipal, industrial, and irrigation developments in three important aspects: 1) the quantity of water needed for domestic and stock purposes is considerably smaller and may, therefore, be provided from considerably thinner and less permeable aquifers; 2) the area within which a well can be constructed for domestic or stock purposes is normally small, usually a farmyard or a suburban lot; and 3) the cost of well construction must be low, which prohibits deep drilling.

In western Illinois, geologic conditions are generally favorable for obtaining private water supplies at reasonable cost. Throughout most of the area, creviced dolomite and limestone are at sufficiently shallow depth to be within reach of private wells. Water-yielding sand and gravel are present in some areas. Sandstone, coal, and fractured shale in the Pennsylvanian system yield sufficient water for small wells in many localities.

Subsurface geologic conditions generally vary little within the limited area of an individual homesite or farm. However, there may be great changes in geologic conditions with depth. Information on depth of aquifers is valuable for planning the type, depth, and size of the intended well.

Perhaps the most important considerations in locating private wells are those of sanitation and convenience of location. Wells should be placed with regard to geologic conditions, surface drainage, topography, and land usage so as to provide maximum protection from harmful bacteria and objectionable inorganic material.

The following suggestions may be helpful in planning for individual or farm supplies.

1) Inventory the water requirements - estimate the amount of water needed for domestic use, stock use, milk cooling, washing, and fire protection.

2) Obtain all available information on the occurrence of water-yielding formations at the location. The maps in this report are designed to give a fundamental understanding of the occurrence and distribution of the water-yielding formations in this area so that the most suitable type of well can be planned. If additional more specific information is desired, address the State Geological Survey, Urbana, Illinois, giving a) location of property by section, township, and range, b) intended use of the water supply, c) estimate of the quantity needed, and d) all information on existing wells on the property or previous drilling attempts.

3) Select a well driller with a reputation for constructing wells that have proved to be trouble-free. Make sure the driller is capable of properly handling the types of aquifers he may encounter at the location. If the well is to be finished in sand and gravel, select a driller experienced in setting well screens.

4) Check with the State Department of Public Health for regulations and suggestions on proper well construction and location and proper pump housing. The State Department of Public Health discourages the use of well pits on Grade A milk farms unless they are built to very rigid specifications. Properly constructed well pits are more expensive than other approved methods of pump installation.

5) Make periodic bacterial analyses of the water supply. Dug wells are more difficult to keep sanitary than are properly constructed drilled wells. Wells drilled into creviced dolomite and limestone formations are, however, also susceptible to bacterial pollution, particularly where the creviced formation is overlain by thin overburden.

Role of the Drilling Contractor

Much of the success of any drilled well depends on the skill and knowledge of the drilling contractor. A drilling contractor has certain duties and responsibilities to his customers.

1) The driller should provide an accurate log of the boring at the time it is completed. The log should include a description of the formations, information on the static water level, basic construction features of the well (length and size of well casing and screen, etc.), and an indication of the capacity of the well as determined by a pumping test. Copies of the driller's log should be filed with the State Geological Survey. Log books may be obtained by drillers without charge from the State Geological Survey.

2) The well should be constructed in accordance with accepted safe sanitary practices. The top of the well should be constructed to prevent surface pollution from entering the well or seeping downward around the casing. It is also desirable that well construction allow for measurement of the depth to water without requiring removal of the pumping equipment.

3) The driller should endeavor to take full advantage of any water-yielding formations he may encounter. In areas where groundwater conditions are generally unfavorable, it takes a skillful driller to obtain the maximum amount of water from a poor formation. Where sand and gravel aquifers are used as a source of groundwater, the driller should select a well screen on the basis of size and sorting of the formation material. After construction the well should be properly developed. A properly screened and developed well in sand and gravel will not pump an objectionable amount of sand or silt during service.

4) It is desirable to save samples at 5-foot intervals for the total depth of drilling, especially for municipal, industrial, irrigation, and school wells. The State Geological Survey files samples of drill cuttings received from drillers. The samples may be sent express collect to the Survey where they will be studied and kept on file for reference. Information obtained from samples is vital in effective rehabilitation of old wells.

COUNTY GROUNDWATER SUMMARIES

Detailed information on groundwater supplies in the counties of western Illinois, north part, follows. These discussions supplement the geologic information shown on the maps in figures 5 and 6 and given in table 1.

Fulton County

Most domestic wells are drilled into Pennsylvanian sandstones that occur a few feet below coal beds, at depths ranging from 50 to more than 300 feet, or into the Keokuk-Burlington limestone, which is encountered at depths ranging from 250 to about 500 feet. The Keokuk-Burlington limestone is sufficiently creviced to yield water for domestic supplies at most, but not all, localities.

Groundwater in the Devonian-Silurian rocks, which occur several hundred feet below the Keokuk-Burlington, is highly mineralized. The deep sandstones, Glenwood-St. Peter and Ironton-Galesville, are permeable and water-yielding, but their use in Fulton County is limited because of poor water quality.

The most favorable areas for sand and gravel wells are the Illinois and Spoon River valleys. Deposits of sand and gravel on the upland are thin and discontinuous.

Henderson County

Excellent water-yielding sand and gravel deposits occur in the valley of the Mississippi River. At many places these deposits extend from a few feet

below the surface to a depth of some 200 feet. They are suitable for development both by driven sand points and by high-capacity drilled or collector-type wells. Because of lateral variations in textures within the river sediments, construction of a high-capacity well at any particular site should be preceded by a small-diameter pilot hole to test the suitability of the deposits at the site.

Domestic wells cannot be made in sand and gravel at all localities on the uplands bordering the Mississippi Valley; however, at most localities it is possible to obtain groundwater from the bedrock formations. The Devonian-Silurian formations occur within 300 feet of the surface in the northern township of the county, whereas the Keokuk-Burlington limestone is less than 350 feet from the surface in the upland south of T. 11 N. (fig. 5). The Galena dolomite (fig. 4) and Devonian limestone supply water to the village well at Biggsville. According to Illinois State Water Survey studies, water in the Galena strata is much more highly mineralized than water in the Devonian strata. Further increase in mineral content of waters with depth limits development of the deep sandstones.

Henry County

Silurian dolomite, ranging in thickness from about 250 feet in the south to more than 400 feet in the north, is the main source of domestic groundwater supplies in Henry County. The most extensive crevicing - and therefore the most favorable water-yielding zone - is in the upper 125 feet of the dolomite.

In most of the county the Devonian and Silurian rocks are overlain by Pennsylvanian rocks. Sandstone, fractured shale, and coal in the Pennsylvanian rocks yield sufficient water for domestic use at some localities. The Devonian limestone is reported to be generally "tight" except along the Rock River where it crops out or underlies river fill.

The Glenwood-St. Peter and Ironton-Galesville sandstones are sources of groundwater at Kewanee and Galva.

Highly permeable sand and gravel aquifers suitable for industrial development occur in the extensive lowland of the Green River in the northern part of the county. The deposits thicken north of the Green River toward the axis of a bedrock valley that was the former course of the Mississippi River eastward from the northern tip of Rock Island County. South and west of the Wisconsin glacial front (fig. 6) sand and gravel deposits generally are thin and discontinuous.

Knox County

Water-yielding sand and gravel deposits in Knox County are spotty in distribution beneath the upland. At Galesburg and westward sand and some gravel, suitable mainly for small groundwater supplies, occur in a drift-filled valley in the bedrock. Favorable deposits also occur in the Spoon River valley, although exploration is necessary to locate sites favorable for wells. Sand and gravel deposits rarely are encountered in a belt south and east of Galesburg, where the drift is thin and where bedrock crops out along most of the creeks (fig. 6).

Bedrock sources of groundwater include sandstone and fractured shale in the Pennsylvanian system, and underlying limestone and dolomite formations.

The Keokuk-Burlington limestone, present south of Galesburg and Knoxville, is a dependable aquifer for farm supplies, with wells penetrating from 30 to 70 feet into the limestone. The Silurian dolomite generally is better creviced than the shallower Keokuk-Burlington strata and is therefore capable of somewhat greater yields. Drillers report that the best water-yielding zone in the Silurian is in the upper 125 feet and that the lower half commonly is "tight." The Silurian thickens from less than 90 feet to almost 300 feet between the southwestern and northeastern corner of the county, whereas the Devonian limestone averages about 90 feet in thickness.

The Glenwood-St. Peter and the Ironton-Galesville sandstones are groundwater sources for city wells at Galesburg, Knoxville, and Abingdon and are the most dependable aquifers for high-capacity wells in the county.

McDonough County

The top of the water-yielding Keokuk-Burlington limestone is reached within 175 feet of the surface in the western part of McDonough County and within 250 feet in the eastern part. Drillers report the Keokuk-Burlington strata to be a dependable source of water for domestic supplies at most localities, with depth of penetration into the limestone ranging from 75 to 150 feet.

Pennsylvanian and Warsaw shales (figs. 4 and 5) overlie the Keokuk-Burlington limestone. Sandstone or coal beds in the Pennsylvanian rocks yield groundwater locally for small to moderate supplies. Many wells in the vicinity of Colchester, including the city wells, obtain water from old mine workings in the No. 2 coal at a depth of about 80 feet.

Silurian rocks are absent in the western two-thirds of the county and are less than 50 feet thick in the eastern part. Devonian rocks are from 0 to 150 feet thick but are tight at most places. In southwestern McDonough County, in the vicinity of the Colmar-Plymouth oil field, drillers report that where the Devonian is not tight it contains salt water.

The deepest aquifers used for municipal supply in the county are at Bushnell where the Galena-Platteville dolomite and St. Peter sandstone are penetrated in a 1510-foot well (table 1).

Discontinuous sand and gravel deposits are present in the drift, mainly in the eastern three-fourths of the county. The most permeable deposits are in the valley of the La Moine River in the southwestern township of the county. Favorable deposits also may occur in a drift-filled bedrock valley that runs northeast from this part of the La Moine valley about six miles south of Colchester and three miles south of Macomb.

Mercer County

Extensive, thick, permeable sand and gravel deposits occur along the Mississippi River and are suitable for the use of driven sand points and for high-capacity drilled or collector-type wells. Thinner, less continuous sand and gravel deposits occur in some of the tributaries of the Mississippi, as for example the Edwards River, but locating suitable sites for wells in such deposits may require extensive testing.

Studies of the glacial deposits in the county indicate that the townships most favorable for the finding of water-yielding sand and gravel in upland drift are T. 13 N., Rs. 2, 3, and 4 W.; T. 14 N., R. 1 W.; and T. 15 N., R. 5 W. In these

areas the deposits are fairly thick, exceeding 200 feet in places, and are known to contain suitable sand and gravel for drilled wells.

Most farm wells are in the Pennsylvanian sandstones, coal or fractured shale, Devonian limestone, or Silurian dolomite. The Silurian dolomite, particularly the upper 100 feet, is generally better creviced than the Devonian. Common procedure in construction of farm wells in Mercer and adjoining counties is to drill and drive 6-inch casing into the top of the Devonian or Silurian to shut off water from the glacial drift and the Pennsylvanian formations, reduce to 5-inch, and drill open hole to total depth.

The Glenwood-St. Peter sandstone is the principal deep aquifer used in Mercer County.

Peoria County

The most important aquifer for municipal and industrial groundwater in Peoria County is the Sankoty sand (fig. 4), which forms a thick fill in and along the Illinois Valley. The thickness along the Illinois Valley varies from 50 to 150 feet, and under the uplands it may reach a possible maximum of almost 300 feet. Younger glacial outwash deposits, overlying the Sankoty sand along the Illinois, also are water-yielding and are a source of supply in shallower wells in the bottom lands.

In the western three-fourths of Peoria County, away from the Illinois River, sand and gravel deposits are scattered and thin. Possibilities of penetrating water-yielding sand and gravel are somewhat better east of the Wisconsin drift margin (see fig. 6) than farther west where the older glacial deposits are thin.

Bedrock conditions are not favorable for drilled wells for domestic groundwater supplies. Some water is obtained from sandstones, coal, and fractured shale in the Pennsylvanian rocks in wells as much as 350 feet deep, but drilling into the Keokuk-Burlington and Devonian-Silurian is not recommended because of the poor quality of the water. The State Water Survey reports the water of the Keokuk-Burlington to be more highly mineralized (8000 ppm) than that from any other formation in the area.

The Glenwood-St. Peter sandstone is the deepest aquifer penetrated for groundwater in Peoria County. The Ironton-Galesville sandstone, about 1000 feet below the St. Peter, probably contains water too highly mineralized for most purposes.

Detailed information on the geology, hydrology, and chemistry of groundwater in the Peoria region (fig. 1) may be found in Illinois State Geological Survey Bulletin 75 (also published as State Water Survey Bulletin 39).

Stark County

Sand and gravel outwash associated with the Wisconsin drift border occurs in Stark County southeast of Wyoming (fig. 6). This is the most extensive deposit of sand and gravel in the county and is the source of water for many drilled, driven, and dug wells. Most of the drilled wells are less than 50 feet deep and are constructed with commercial well screens.

Pockets of sand and gravel occur in the valley fill of the Spoon River and at various depths in the glacial deposits beneath the uplands. The eastern part of the county, within or near the Wisconsin drift border, is more favorable for developing groundwater supplies in sand and gravel than the western part.

Because the Keokuk-Burlington limestone is absent in Stark County (see fig. 5) shallow bedrock sources of groundwater include only sandstone, coal, and fractured shale in the Pennsylvanian system and the Devonian-Silurian rocks. The Pennsylvanian rocks range from 300 to 500 feet thick in the county, and the most favorable sources of groundwater are in the upper 200 feet. Deeper wells in the county obtain water from the Galena-Platteville dolomite and the Glenwood-St. Peter sandstone (fig. 4).

Details on the geology, hydrology, and chemistry of groundwater in Stark County are given in Illinois State Geological Survey Bulletin 75.

Rock Island County

The Silurian dolomite, which is reached at depths ranging from a few feet below the surface in the northern part of Rock Island County to about 400 feet in the southeast corner, is the main source of domestic groundwater supplies. Water-filled fractures are most likely to occur in the upper 125 feet of the dolomite, whereas the lower part is commonly "tight." Drillers report that the Devonian limestone, which attains a maximum thickness of almost 200 feet in the county, is usually tight and not water-yielding.

Many domestic wells in this county obtain water from sandstone, coal, or fractured shale in the Pennsylvanian rocks, although in wells penetrating the Silurian strata the Pennsylvanian and underlying Kinderhook shales are cased off.

Of the deep aquifers in the Tri-Cities, the Glenwood-St. Peter, Ironton-Galesville, and Jordan sandstones (fig. 4) have supplied water for municipal and industrial purposes.

Sand and gravel aquifers are thin and of limited areal extent, except for deposits along the ancient course of the Mississippi River in T. 20 N. (fig. 6). This tract extends eastward into Whiteside County and is one of the main areas of undeveloped groundwater reserves in the State. Sand and gravel deposits along the Mississippi River west of Rock Island and north of East Moline and along the Rock River are thin. Sand and gravel in the drift in the uplands is discontinuous and thin. A thin deposit of water-yielding sand and gravel of undetermined extent has been penetrated in several wells in the southeastern corner of the county.

Warren County

Favorable conditions for domestic wells occur throughout Warren County. Thin sand and gravel deposits are penetrated at many places in the drift, which ranges from 0 to 135 feet thick. Where suitable sand and gravel are absent, wells may be continued into the bedrock and obtain water from sandstones in the Pennsylvanian system, from the Keokuk-Burlington limestone, or from the Silurian dolomite. Where the Keokuk-Burlington is absent in the northern townships of the county, deeper wells obtain water from the Silurian dolomite. In the southwestern quarter of the county the Silurian is absent, so most bedrock wells do not go deeper than the Keokuk-Burlington strata.

Larger groundwater supplies, for municipalities and industries, are obtained from the St. Peter and Galesville sandstones, depths of which are shown in table 1.

SUGGESTED READING

Bedrock topography of Illinois: Leland Horberg, Illinois Geol. Survey Bull. 73, 1950.

Cisterns: Illinois Dept. of Public Health Circ. 129, 1949.

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Public ground-water supplies in Illinois: compiled by Ross Hanson, Illinois Water Survey Bull. 40, 1950.

Rehabilitation of sandstone wells: J. B. Millis, Illinois Water Survey Circ. 23, 1946.

Significance of Pleistocene deposits in the groundwater resources of Illinois: J. W. Foster, Econ. Geol., v. 48, no. 7, November 1953.

Stratigraphy and geologic structure of northern Illinois: F. T. Thwaites, Illinois Geol. Survey Rept. Inv. 13, 1927.

Wells, dug, drilled, driven: Illinois Dept. of Public Health Circ. 14, 1951.

Other general reports on groundwater geology in Illinois similar in purpose and scope to the present study include the following circulars: C. 192, Water wells for farm supply in central and eastern Illinois; C. 198, Groundwater possibilities in northeastern Illinois; C. 207, Groundwater in northwestern Illinois; and C. 212, Groundwater geology in southern Illinois. These circulars, published by the Illinois State Geological Survey, are available free on request.

Topographic maps are available for the area covered in this report. These maps are on a scale of approximately 1 inch to the mile, but in the Tri-Cities, Peoria, and Canton-Lewistown regions they are available also on a scale of approximately 2 1/2 inches to the mile. They are printed by quadrangles and may be obtained from the Illinois State Geological Survey, Urbana, Illinois, or from the United States Geological Survey, Washington 25, D. C., for 20 cents each. Index maps showing the topographic map coverage of the State are free on request.

Detailed geologic reports have been published or are in preparation for the following quadrangles: Edgington, Milan, Alexis, La Harpe, Good Hope, Avon, Canton, Peoria, Colchester, Macomb, Vermont, Havana, Beardstown, and Glasford. Information on these reports may be obtained from the Illinois State Geological Survey in Urbana.

Table 1. - Key Wells Showing Sequence and Depths of Formations at Selected Locations

Dash (-) indicates formation absent. TD = total depth of well. See fig. 4 for information on rock types, water-yielding characteristics, and drilling and well-construction procedures.

Well no.	Location (See fig. 2)	Surface elev. (Ft. above sea level)	Drift	Pennsylvanian	St. Louis-Warsaw	Keokuk-Burlington	Kinderhook	Devonian - Silurian	Maquoketa	Galena-Platteville	Glenwood - St. Peter	Shakopee - Franconia	Ironton - Galesville
			DEPTH OF FORMATIONS (IN FT.)										
1	Rock Island 19-18N 1E	600	0 to 90	90 to 143	-	-	-	143 to 486	486 to 703	703 to 1032	1032 to 1145	1145 to 1904 TD	
2	Rock Island 8-17N 1W	611	0 to 71	-	-	-	-	71 to 481	481 to 711	711 to 1041	1041 to 1161	1161 to 2010	2010 to 2090 TD
3	Henry 36-17N 4E	637	0 to 15	15 to 184	-	-	-	184 to 593	593 to 715	715 to 1119	1119 to 1257 TD		
4	Mercer 13-15N 4W	765	0 to 80	80 to 200	-	-	200 to 307	307 to 639	639 to 644 TD				
5	Henry 28-15N 5E	820	0 to 120	120 to 365	-	-	-	365 to 810	810 to 998	998 to 1355	1355 to 1555	1555 to 2415	2415 to 2484 TD
6	Mercer 17-14N 3W	730	0 to 100	100 to 135	-	-	-	135 to 560	560 to 762	762 to 1065	1065 to 1145	1145 to 2165 TD	
7	Henry 30-14N 2E	824	0 to 100	100 to 370	-	-	370 to 400	400 to 750	750 to 965	965 to 1268	1268 to 1369 TD		

8	Henry 27-14N 4E	845	0 to 50	50 to 350	-	-	-	350 to 860	860 to 1025	1025 to 1350	1350 to 1510 TD		
9	Stark 23-14N 7E	804	0 to 70	70 to 509	-	-	509 to 519	519 to 1015	1015 to 1230	1230 to 1570	1570 to 1660	1660 to 2015	2015 to 2050 TD
10	Warren 1-12N 2W	700	0 to 133	133 to 210	-	210 to 215	215 to 320	320 to 534	534 to 720	720 to 1031	1031 to 1165	1165 to 1215 TD	
11	Stark 1-12N 6E	705	0 to 210	210 to 401	-	-	401 to 535	535 to 933	933 to 1124	1124 to 1400 TD			
12	Warren 29-11N 2W	740	0 to 53	53 to 72	-	72 to 168	168 to 444	444 to 585	585 to 780	780 to 1074	1074 to 1230	1230 to 1232 TD	
13	Knox 14-11N 1E	782	0 to 52	52 to 270	-	-	270 to 330	330 to 485	485 to 655	655 to 1065	1065 to 1252	1252 to 2165	2165 to 2436 (2450 TD)
14	Peoria 13-11N 6E	745	0 to 30	30 to 362	-	362 to 440	440 to 655	655 to 1005	1005 to 1195	1195 to 1342 TD			
15	Knox 33-10N 1E	750	0 to 130	130 to 190	-	-	190 to 310	310 to 580	580 to 720	720 to 900	900 to 1210	1210 to 2440 TD	
16	Peoria 31-10N 8E	720	0 to 155	155 to 560	-	560 to 623	623 to 854	854 to 1180	1180 to 1373	1373 to 1525 TD			
17	Henderson 17-9N 4W	670	0 to 65	-	-	-	65 to 183	183 to 270	270 to 469	469 to 735	735 to 887 TD		
18	Knox 10-10N 3E	694	0 to 58	58 to 253	-	253 to 550	-	550 to 775	775 to 967	967 to 1200 TD			
19	Fulton 19-8N 1E	640	0 to 40	40 to 130	-	130 to 285	285 to 570	570 to 672	672 to 810	810 to 1135	1135 to 1170 TD		

Table 1. - Continued

Well no.	Location (See fig. 2)	Surface elev. (Ft. above sea level)	DEPTH OF FORMATIONS (IN FT.) Drift	Pennsylvanian	St. Louis-Warsaw	Keokuk-Burlington	Kinderhook	Devonian - Silurian	Maquoketa	Galena-Platteville	Glenwood - St. Peter	Shakopee-Franconia	Ironton - Galesville
20	Peoria 10-8N 6E	720	0 to 30	30 to 490	-	490 to 695	695 to 880	880 to 1145 TD					
21	McDonough 32-7N 4W	730	0 to 60	60 to 100	100 to 163	163 to 320	320 to 608	608 to 744	744 to 775	775 to 1047	1047 to 1202 TD		
22	McDonough 33-7N 1W	651	0 to 120	120 to 138	138 to 240	240 to 410	410 to 660	660 to 737	737 to 905	905 to 1200	1200 to 1470	1470 to 1510 TD	
23	Fulton 27-7N 4E	670	0 to 42	42 to 367	-	367 to 582	582 to 808	808 to 871	871 to 1180	1180 to 1490	1490 to 1700 TD		
24	McDonough 33-6N 2W	695	0 to 95	95 to 155	155 to 220	220 to 403	403 to 651	651 to 730	730 to 883	883 to 1077 TD			
25	Fulton 29-6N 3E	680	0 to 30	30 to 300	300 to 410	410 to 595	595 to 855	855 to 960	960 to 1155	1155 to 1380 TD			
26	McDonough 33-5N 4W	608	0 to 18	-	-	18 to 276	276 to 500	500 to 555	555 to 678	678 to 948	948 to 1290	1290 to 1955 TD	

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